



Prof. Philip Koopman

Automated Vehicle Safety Update for 2021

February 2021

Carnegie
Mellon
University



@PhilKoopman

- Where is the industry in general as of early 2021?
- Beyond the SAE Levels
 - Role of human vs. technology
- Industry trends for 2021
 - Role of standards
 - Technical challenges
 - Organizational challenges



Low Speed Shuttles

■ Low speed shuttles

- Up to 15 passengers
- Fixed route at perhaps 5-10 mph
- Demonstrations in cities worldwide

■ Safety approach

- Slow speed limits kinetic energy
- Often a non-driver safety conductor

■ Example Mishaps

- Shuttle hit by backing truck (Las Vegas, 2017)
- False alarm emergency stop with passenger injury (Ohio 2020)

NHTSA lifts suspension of EasyMile vehicles



Smart Columbus

<https://bit.ly/39ki41t>

By [Cailin Crowe](#)

Updated May 19 2020, 10:30 a.m. EDT • Published Feb. 27, 2020

- **Parcels to stores, houses**
 - Short range delivery
 - Roads, bike lanes, sidewalks
 - Demonstrations in several cities

- **Safety approach**
 - Early: trailing vehicle
 - Later: remote human

- **Example Incidents**
 - Sidewalk bot blocks wheelchair ramp (Pittsburgh, 2019)
 - Tension over use of sidewalk space

Nuro Gets First Commercial Autonomous Vehicle Permit in California

Prepare yourself mentally to see a Prius driving itself if you live in the Bay Area.

BY JAY RAMEY ♦ DEC 31, 2020



■ Automated driving of car or truck

- Continuous driver supervision
- OEMs in production already

■ Safety approach

- Human driver monitors automation
- Human driver responsible for safety

■ Example Mishaps

- Multiple fatal Tesla crashes
 - Issue: driver complacency
 - Issue: under 10 seconds from OK to fatal crash
- Tempe Arizona fatality in testing (Tempe, 2018)

NTSB: Tesla Autopilot, distracted driver caused fatal crash

<https://bit.ly/3bnk3EZ>

By TOM KRISHER February 25, 2020



Fully Autonomous Operation

■ Fleet vehicles

- Waymo robotaxis deployed a limited scale
- Middle-mile trucks gained interest in 2020
- Many players pushing hard in this area

■ Safety approach

- Early: Human safety driver
- Later: Human on-call if car asks for help

■ Example incidents

- California reports indicate minor incidents in testing

Waymo's robo-taxi service opens to the public in Phoenix

Reuters

October 8, 2020 9:15 AM

AI

f t in



<https://bit.ly/39j4yeC>

Waymo's fully self-driving Jaguar I-PACE electric SUV
Image Credit: Waymo

■ Consolidation in the “race” to autonomy

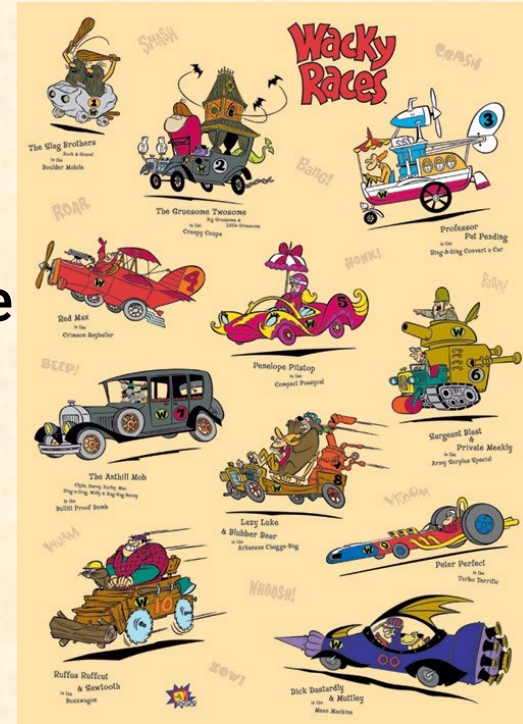
- It takes huge resources to succeed
- Trend to OEM + ADS supplier teaming
- Smaller players fail, team, or acquired over time

■ Fully autonomous pivot toward freight

- Low kinetic energy for last mile service
- Middle mile highways less chaotic than urban













■ Shift of “SAE Level 3” vehicles to L3+

- **Strict L3 means human driver supervision**
- **OEMs shifting to L3+ with car safe stopping on its own**



<https://bit.ly/3s9ZzW9>

A User-Centric Classification

Operating Mode	Human Role	Driving	Driving Safety	Other Safety	
ASSISTIVE	Driving				Driver Assistance
SUPERVISED	Eyes ON the road				
<hr/>					
AUTOMATED	Eyes OFF the road				Automated Driving
AUTONOMOUS	No human driver				
Vehicle Automation Modes					

Standards-Based Engineering Approach

SYSTEM SAFETY	UL 4600		Safety Beyond Dynamic Driving	HIGHLY AUTOMATED VEHICLE SAFETY CASE UL 4600
DYNAMIC DRIVING FUNCTION	ISO/PAS 21448	SaFAD/ISO TR 4804	Environment & Edge Cases	
FUNCTIONAL SAFETY	ISO 26262		Equipment Faults	
CYBER-SECURITY	SAE J3061	SAE 21434	Computer Security	
VEHICLE SAFETY	FMVSS	NCAP	Basic Vehicle Functions	

2021 Technical Safety Challenges

<https://bit.ly/3q7VCzv>



- Perception & prediction
 - Safety of machine learning-based functions
 - Need more than object motion tracking
- Safety of Intended Function (SOTIF)
 - Drive/Fix/Drive iteration with lots of testing
 - Waymo: 6M test miles; 65K deployed miles
 - How will safety be argued for larger fleets?
 - Likely will involve UL 4600 concepts and safety cases
- Getting from “works OK” to “safe”
 - You can brute force the first few “nines” ... but not all of them.
 - Field feedback into safety cases

Developing Trust for Full Automation

- Still an open world with unknowns & changes
 - Want “Positive Risk Balance” (safer than human driver)
 - But ... *no human driver responsible*

■ Use Positive Trust Balance

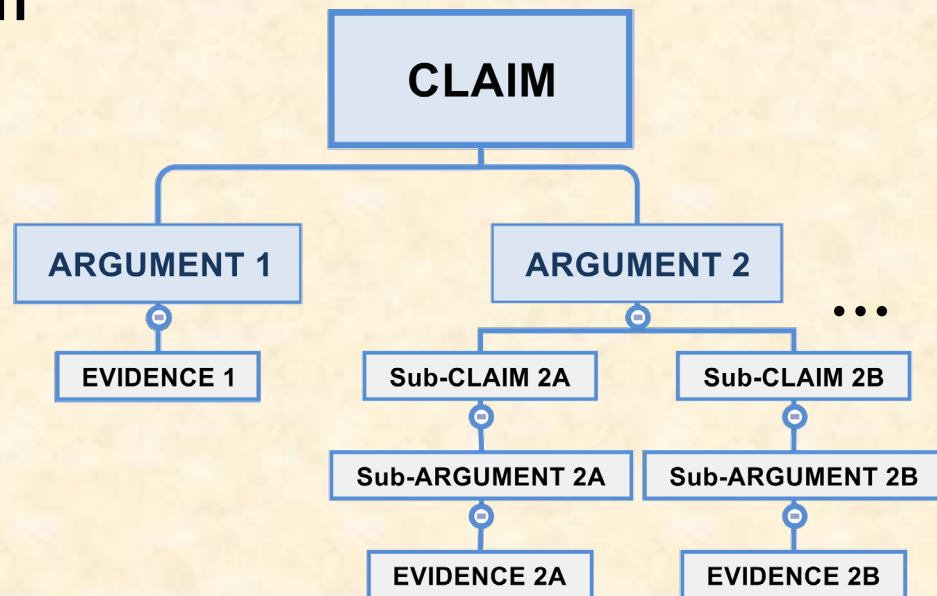
- Engineering rigor
- Practicable validation
- Strong safety culture
.... and ...
- Field feedback
to handle surprises



- UL 4600 ties feedback to Safety Case

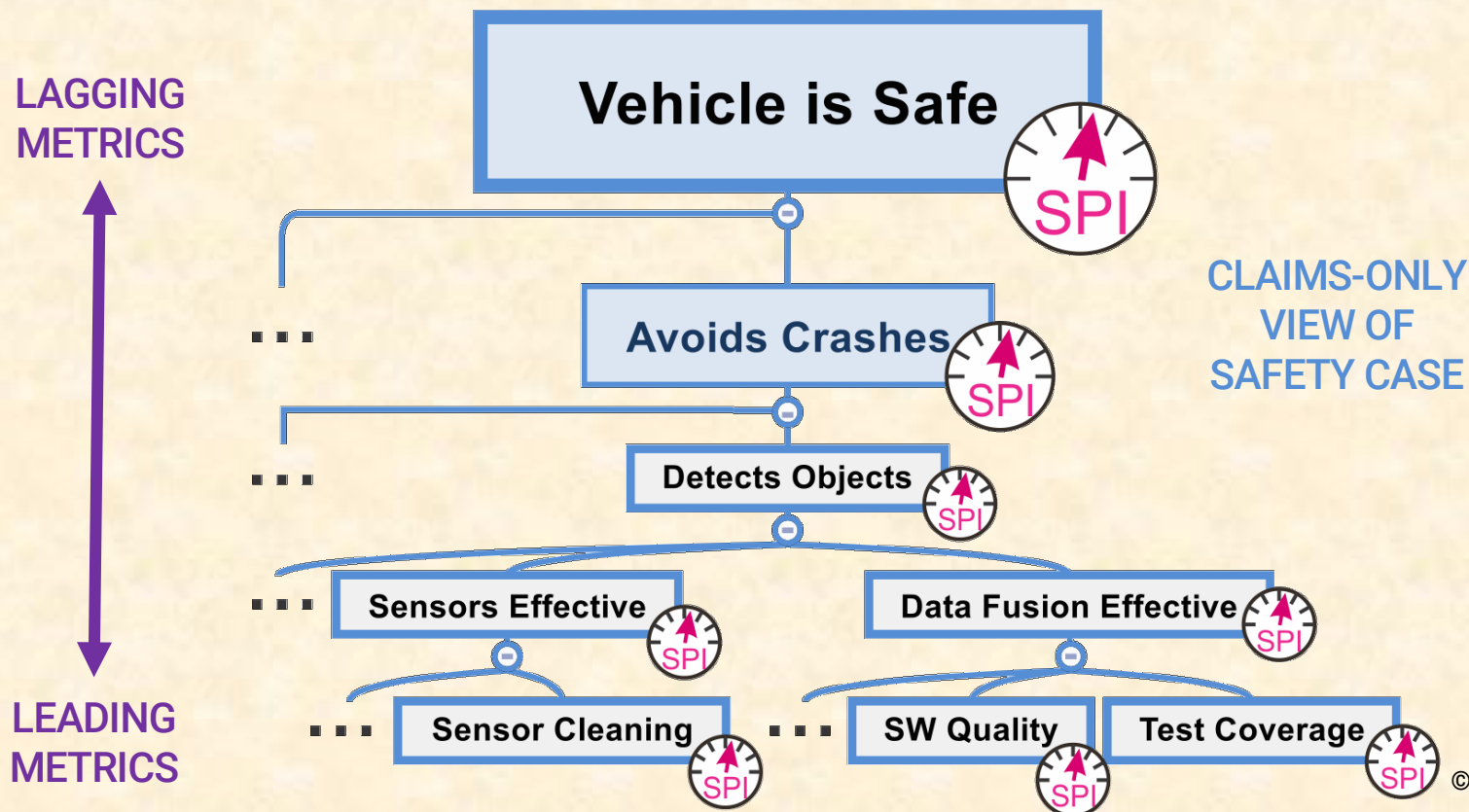
Safety Arguments (Safety Case)

- **Claim** – a property of the system
 - “System avoids pedestrians”
- **Argument** – why this is true
 - “Detect & maneuver to avoid”
- **Evidence** – supports argument
 - Tests, analysis, simulations, ...
- **Sub-claims/arguments address complexity**
 - “Detects pedestrians” // evidence
 - “Maneuvers around detected pedestrians” // evidence
 - “Stops if can’t maneuver” // evidence



Safety Performance Indicators (SPIs)

- SPIs monitor the validity of safety case claims (UL 4600)



Examples of SPIs

- “Acts dangerously” is only one dimension of SPIs
 - Violation rate of pedestrian buffer zones
 - Time spent too close per following distance math
- Components meet safety related requirements
 - False negative/positive detection rates
 - Correlated multi-sensor failure rates
- Design & Lifecycle considerations
 - Design process quality defect rates
 - Maintenance & inspection defect rates
- Is it relevant to safety? → Safety Case → SPIs



2021 Safety Themes

■ Positive Trust Balance:

- Engineering Rigor, Validation, Feedback, Safety Culture
- Standards-driven safety
- Transparency

■ Safety Performance Indicators (SPIs)

- Continual improvement & updates
- Field feedback: development; deployed

■ Scalability past pilot vehicles

- Accurate perception/prediction is still work in progress
- Transition from brute force data to safety case approach



2021 Organizational Safety Challenges

- **Significant pressure to deploy**
 - Flurry of empty driver seat demos in late 2020
 - Can teams take the time needed for safety?
- **Industry transparency needed**
 - Safety collaboration rather than competition
 - Public trust in face of an adverse news event
- **Ensuring robust safety cultures**
 - Silicon Valley culture + automotive culture + no human driver
 - We need to get this right to succeed!



<https://youtu.be/nhqyrze30bk>
Yandex demo video,
Ann Arbor MI, Aug 2020